Data Center Efficiency
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Introduction

- Who Are You?
  - Facility Operations
  - Facility Engineering
  - IT Manager
  - Consultant/Designer
  - Contractor
  - Vendor
  - Other
- What Brings You Here?

Course objectives

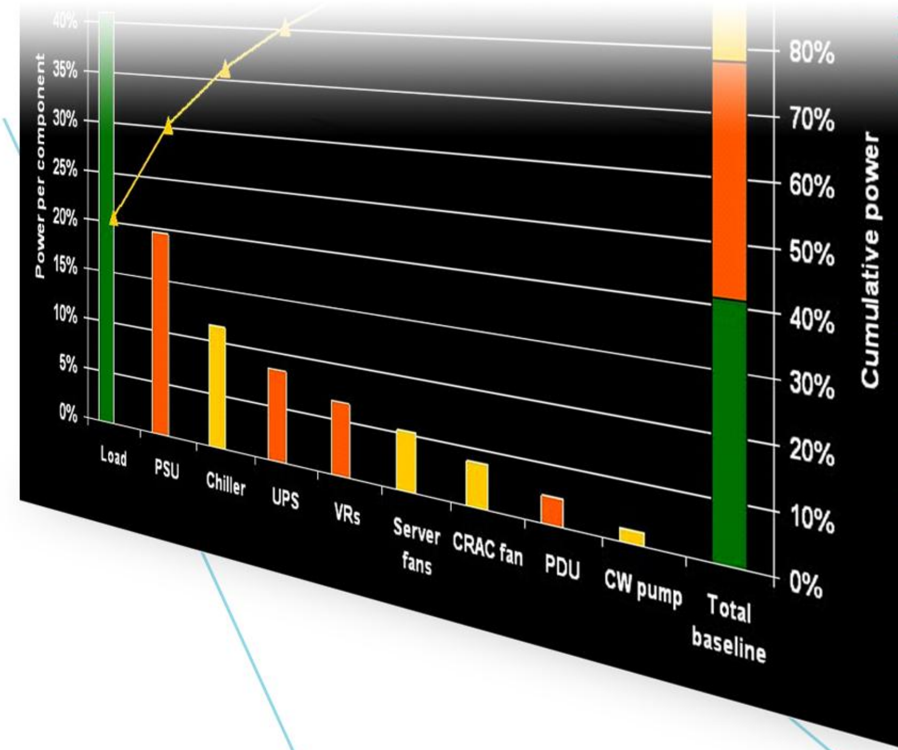
- Raise awareness of data center energy intensity and efficiency opportunities
- Provide resources for on-going use
- Group interaction for common issues and possible solutions

What we will cover

- Energy use in data centers
- Opportunities to increase computational efficiency and the multiplier effect
- Energy intensity growth
- Benchmarking opportunities (how do I stack up?)
- Best practices to improve infrastructure efficiency
- Extending the life and effective capacity of existing data centers
- Technologies coming down the R&D pipeline and lessons learned from demonstrations
- Government programs and information resources

Agenda

Introduction	Dale Sartor
Government programs	
Overview and Benchmarking	
IT Opportunities	
BREAK	
Environmental conditions	Bill Tschudi
HVAC systems	
Electrical systems	
Assessment tools	
Resources	



Overview of Data Center Energy Use

Dale Sartor, PE

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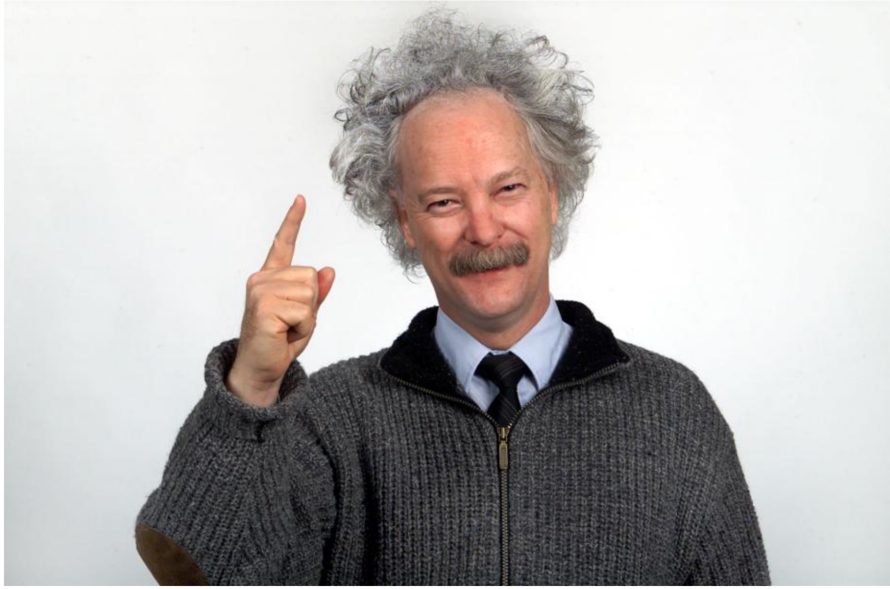
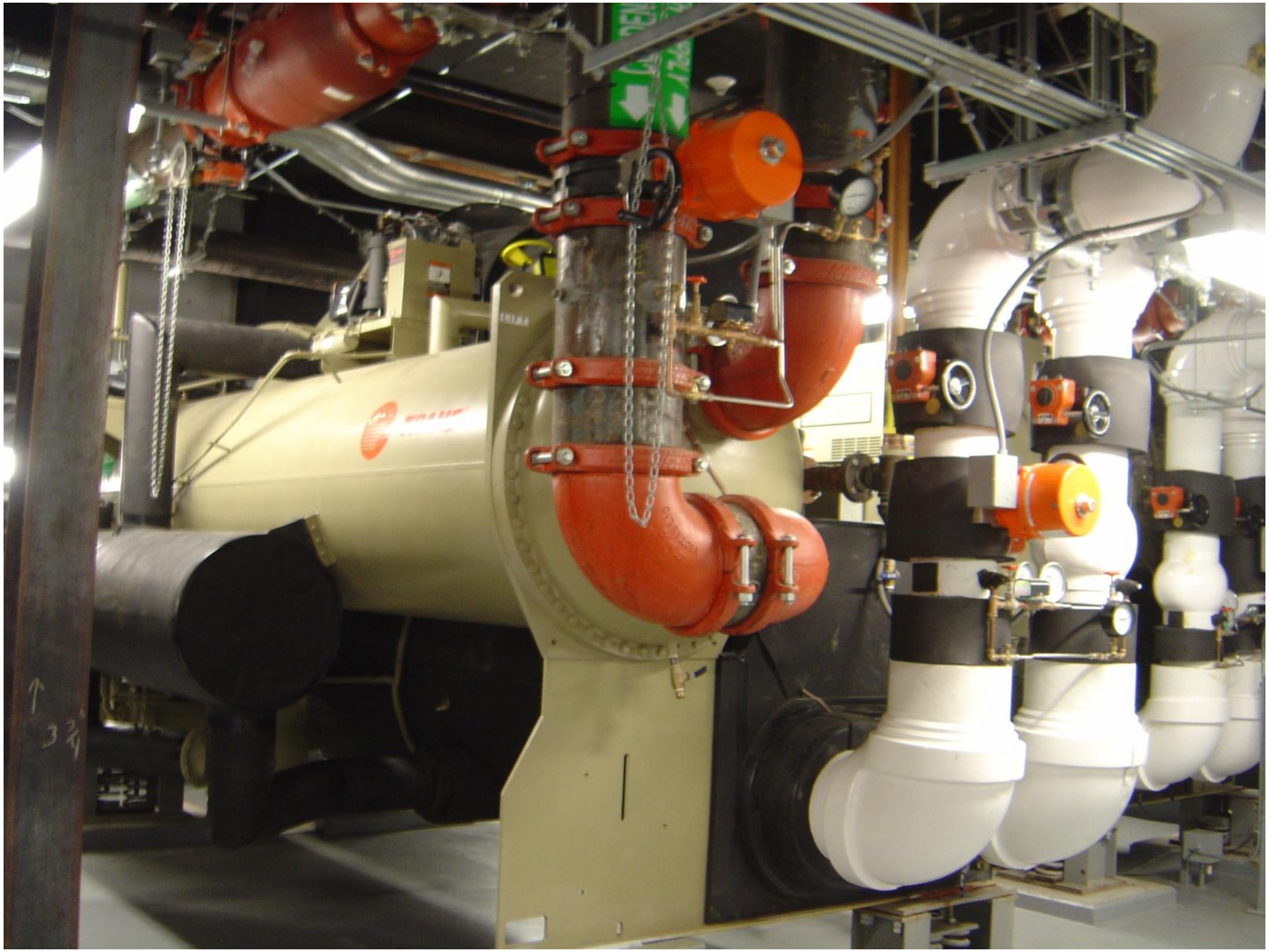


Data Centers are INFORMATION FACTORIES..

- Data centers are energy intensive facilities
  - Server racks now designed for more than 25+ kW
  - Surging demand for data storage
  - Typical facility ~ 1MW, can be > 20 MW
  - Nationally 1.5% of US Electricity consumption in 2006
  - Projected to double in next 5 years
- Significant data center building boom
  - Power and cooling constraints in existing facilities
  - Utility distribution constraints

…Resembling large industrial facilities





CONDENSER WATER RETURN

…Containing specialized equipment

Energy issues abound

- Over the next five years, power failures and limits on power availability will halt data center operations at more than 90% of all companies

  (AFCOM *Data Center Institute's Five Bold Predictions, 2006)*

- By 2008, 50% of current data centers will have insufficient power and cooling capacity to meet the demands of high-density equipment

  (Gartner press release, 2006)

- Survey of 100 data center operators: 40% reported running out of space, power, cooling capacity without sufficient notice

  (Aperture Research Institute)

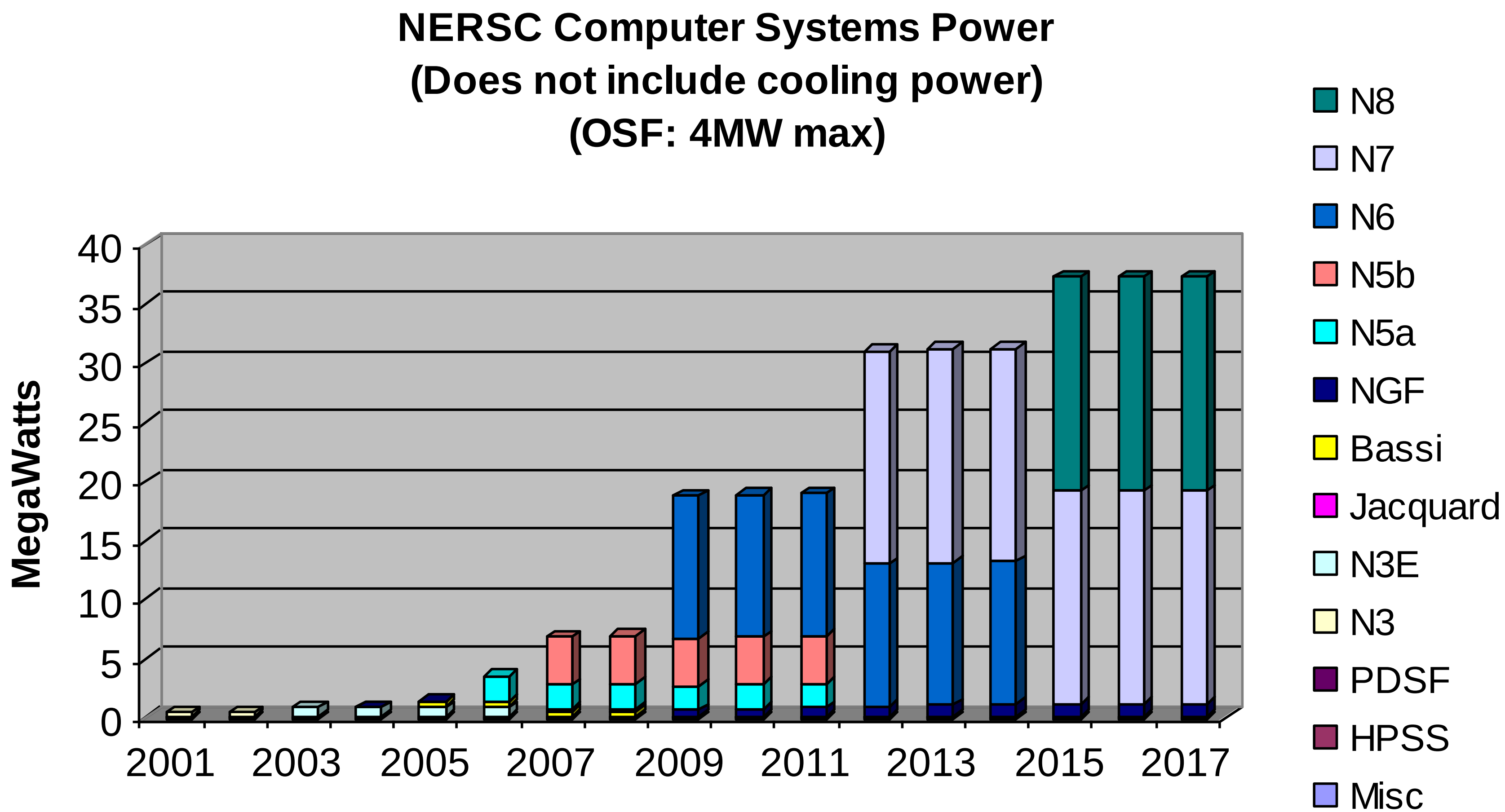
The Rising Cost of Ownership

- From 2000 – 2006, computing performance increased 25x but energy efficiency only 8x
  - Amount of power consumed per $1,000 of servers purchased has increased 4x
- Cost of electricity and supporting infrastructure now surpassing capital cost of IT equipment
- Perverse incentives -- IT and facilities costs separate

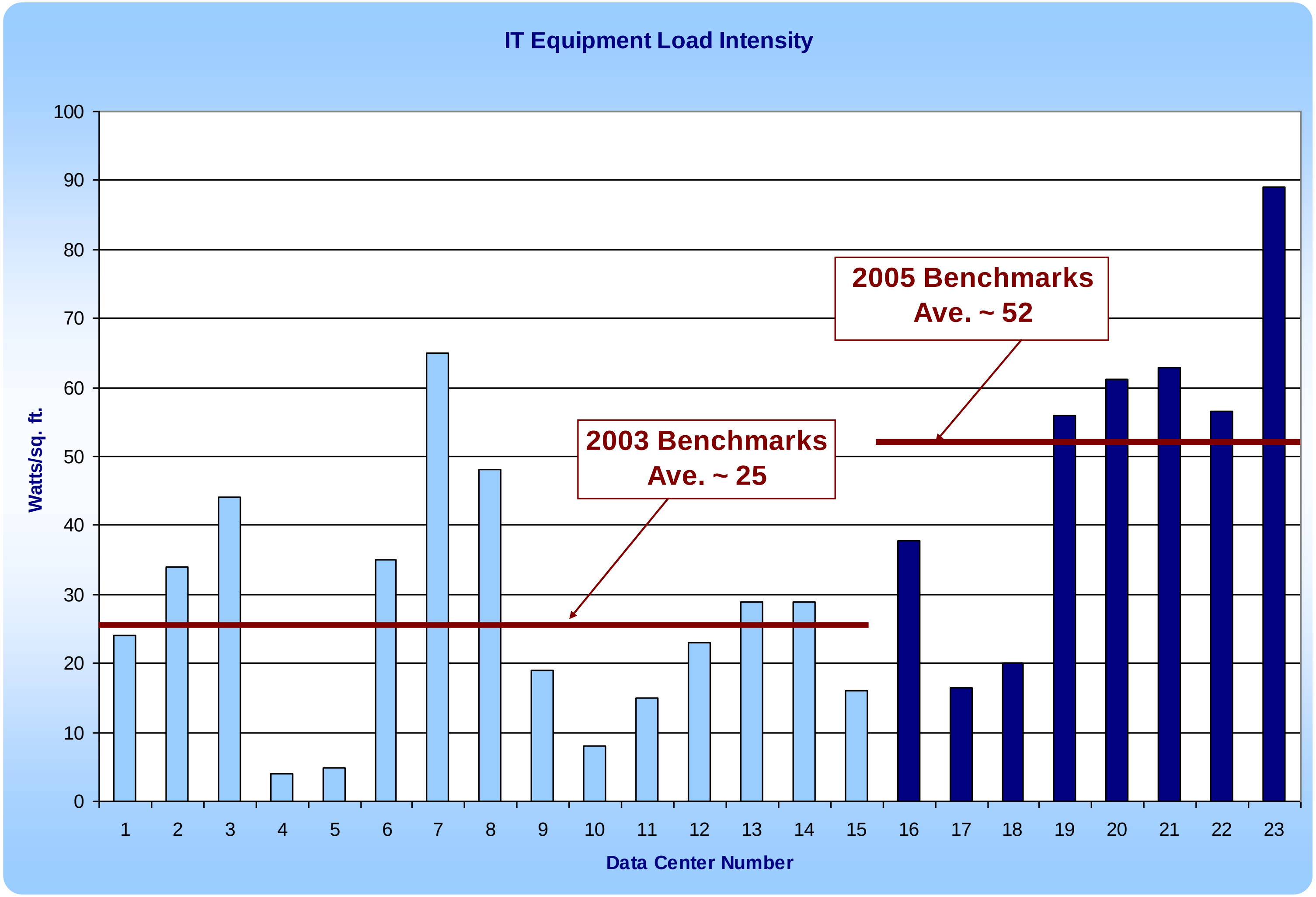
Source: The Uptime Institute, 2007

LBNL feels the energy cost pain!

LBNL Super Computer systems power:



IT equipment load density



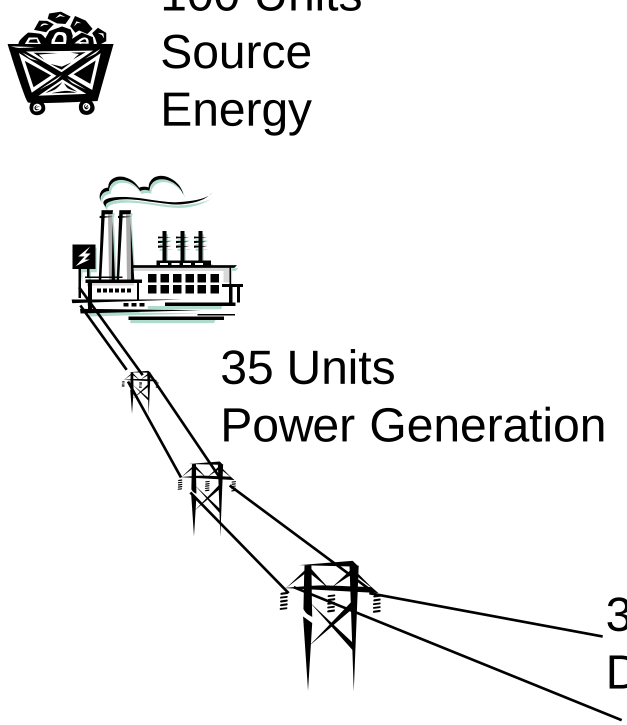
Data center definitions

- Server closet < 200 sf
- Server room <500 sf
- Localized data center <1,000 sf
- Mid-tier data center <5,000 sf
- Enterprise class data center 5000+ sf

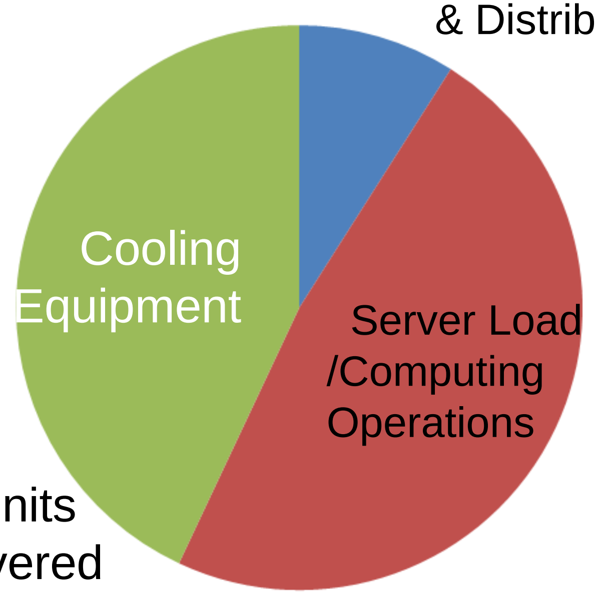
Focus today's training on larger data centers—however most principles apply to any size center

Data center energy efficiency = 15% (or less)

Energy Efficiency = Useful computation / Total Source Energy



Typical Data Center Energy End Use



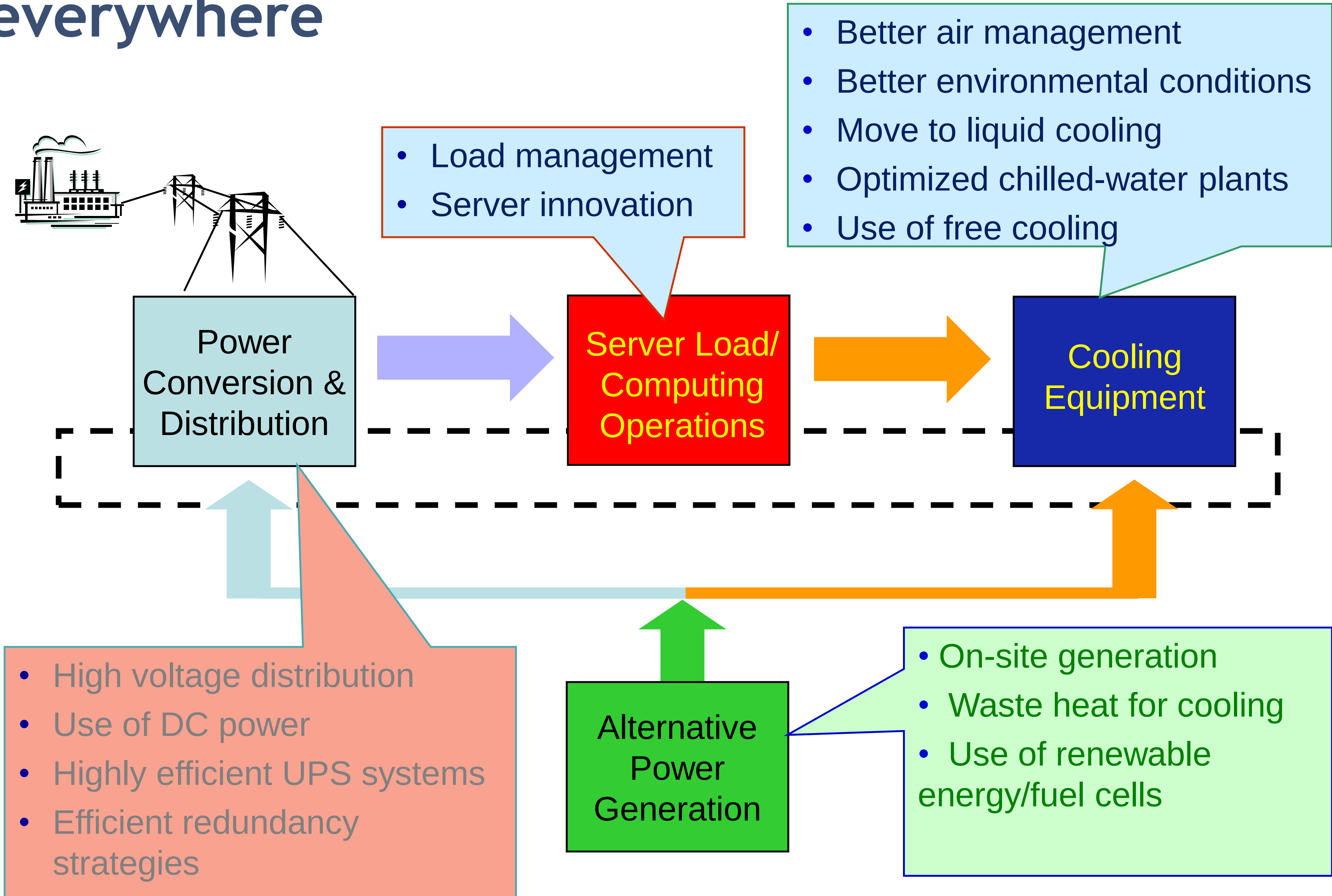
Data center efficiency opportunities

Benchmarking of over 25 centers consistently lead to opportunities

No silver bullet

Lots of silver bb's

Energy efficiency opportunities are everywhere



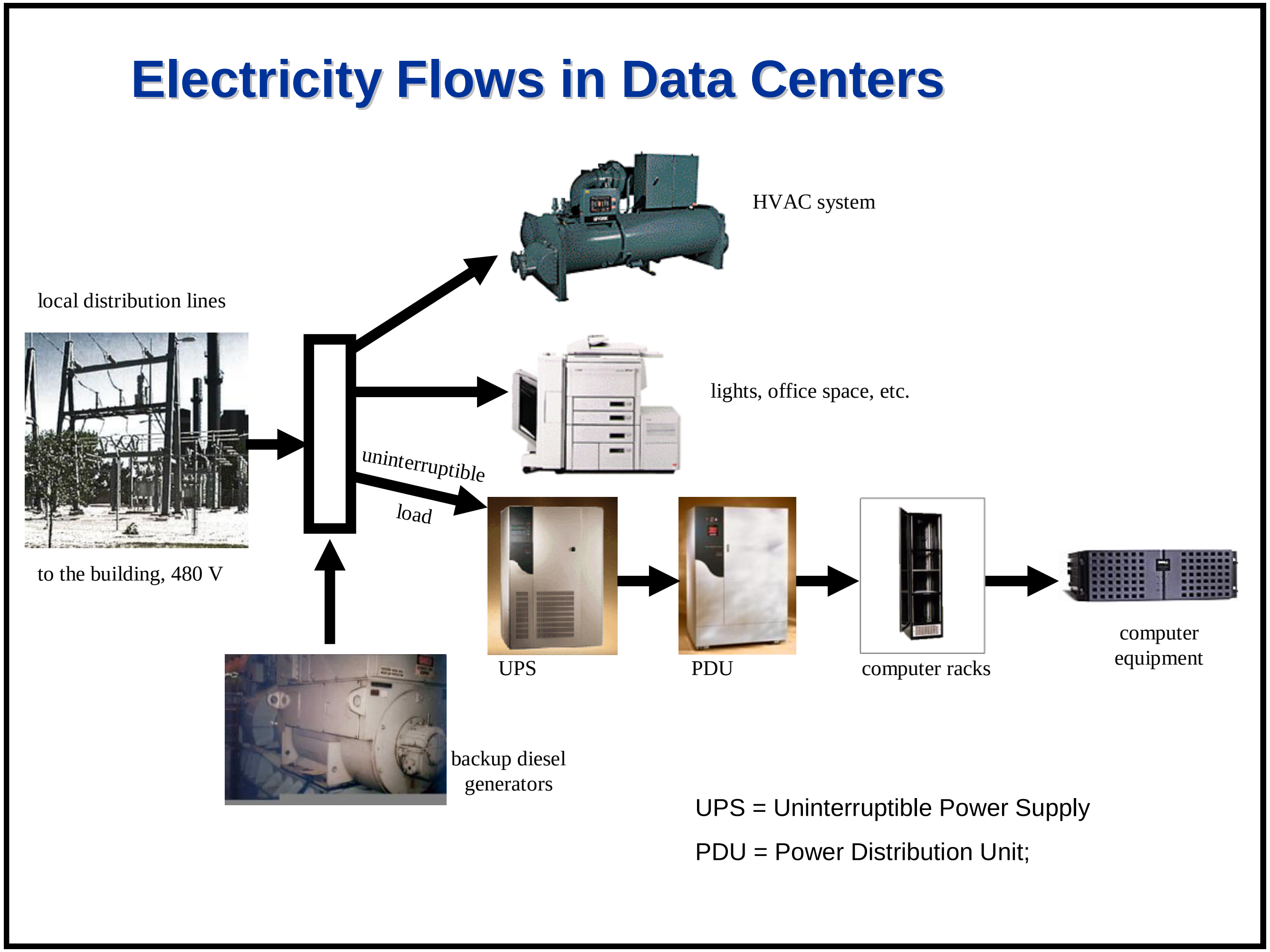
Potential savings

- 20-40% savings typically possible
- Aggressive strategies – better than 50% savings
- Extend life and capacity of existing infrastructure
- But is my center good or bad?

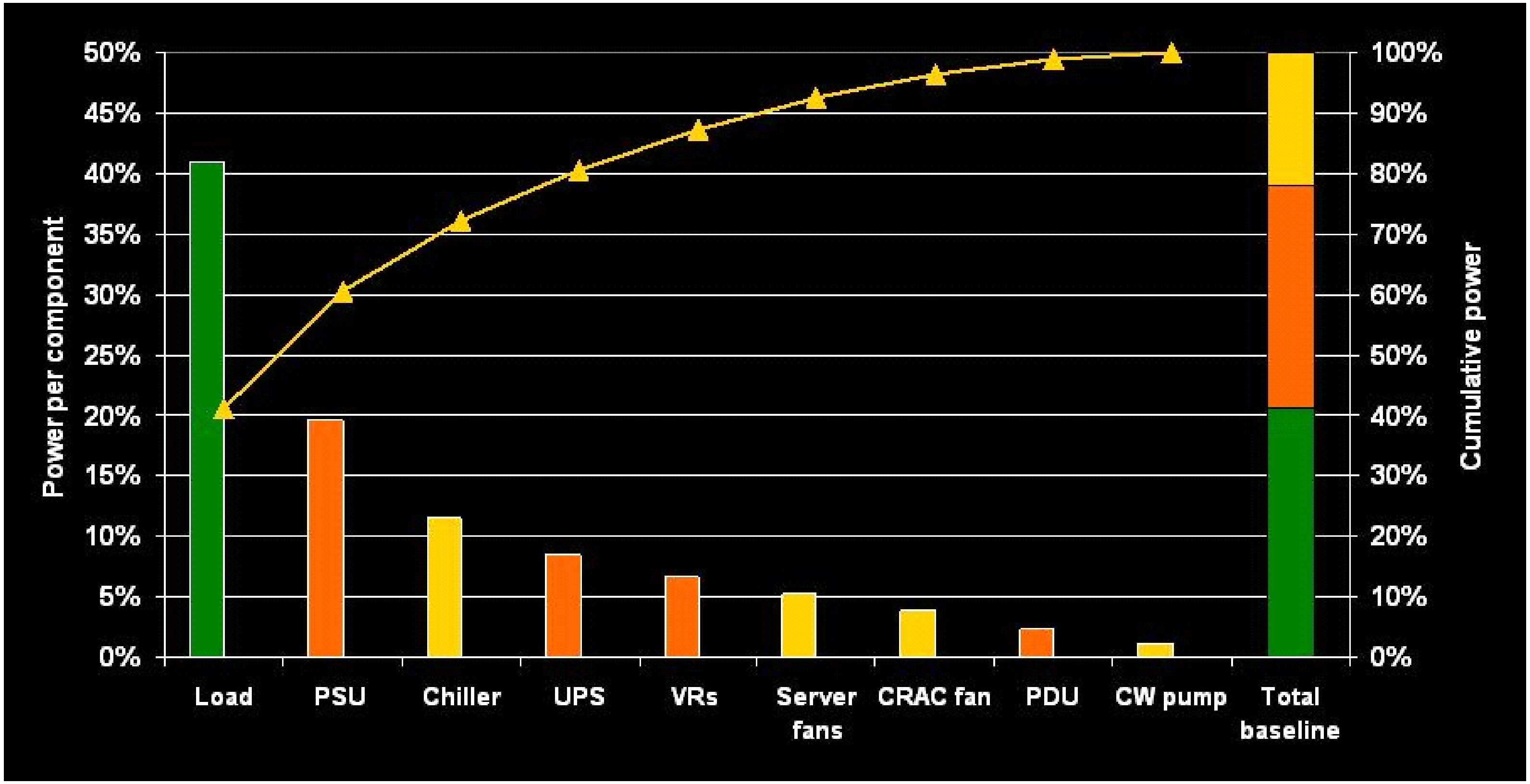
Benchmarking for Energy Performance Improvement:

Energy benchmarking can allow comparison of peers and help identify best practices

Benchmarking energy end use



Overall electrical power use in data centers



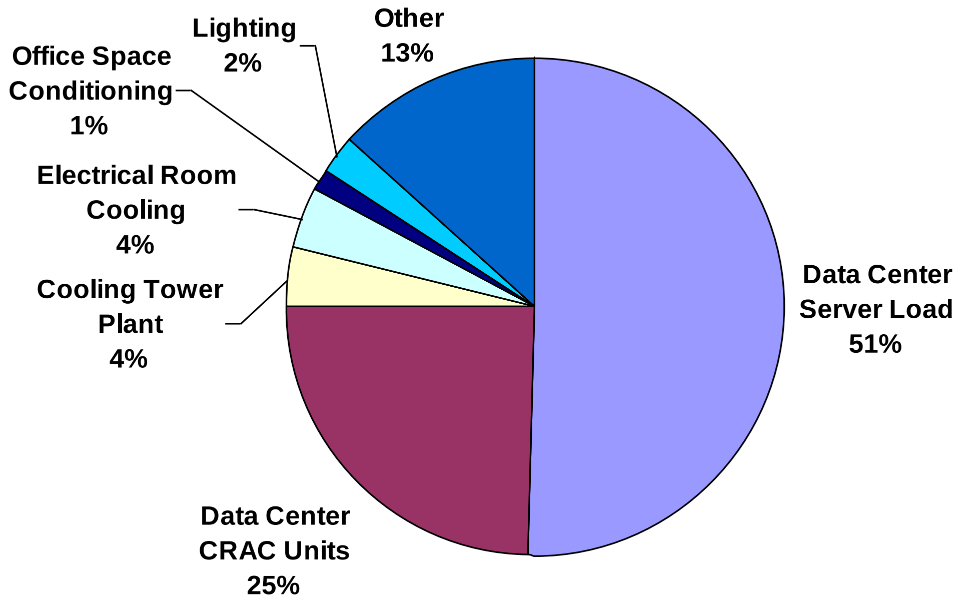
Courtesy of Michael Patterson, Intel Corporation

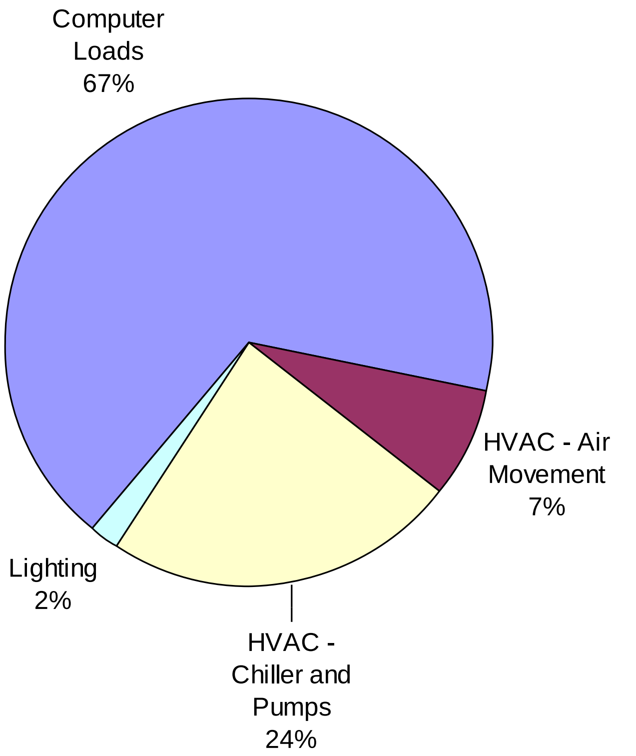
LBNL has conducted benchmark studies of over 30 data centers:

- Found wide variation in performance
- Studied better performing systems
- Identified best practices

Your mileage will vary

The relative percentages of the energy actually doing computing varied considerably.





Data Center performance varies in cooling and power conversion

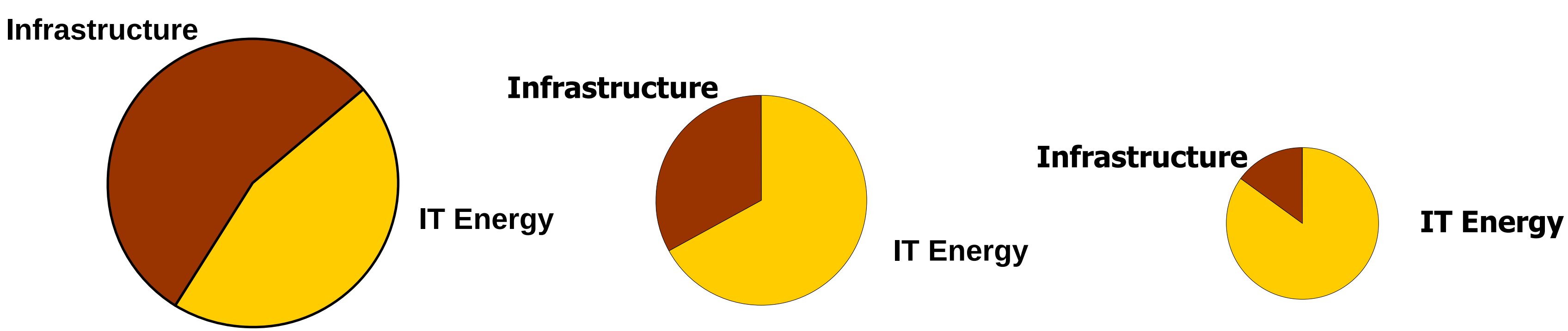
DCiE

Data Center Infrastructure Efficiency

$$\text{DCiE} = \frac{\text{Energy for IT Equipment}}{\text{Total Energy for Data Center}}$$

Typical DCiE (Data Center Infrastructure Efficiency) < 0.5

- Power and cooling systems are far from optimized
- *Less than half of the power is for the servers*

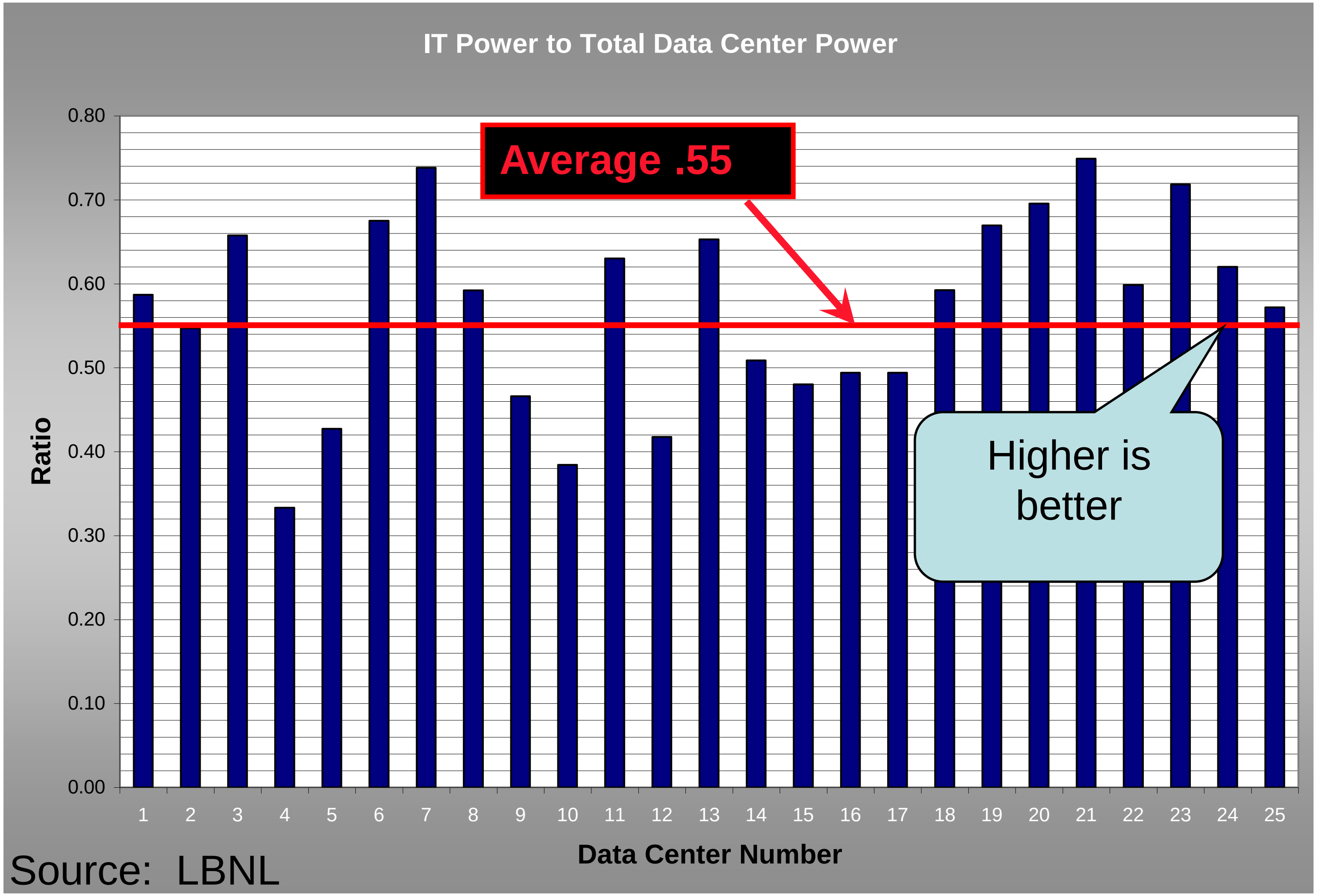


Typical Practice
DCiE < 0.5

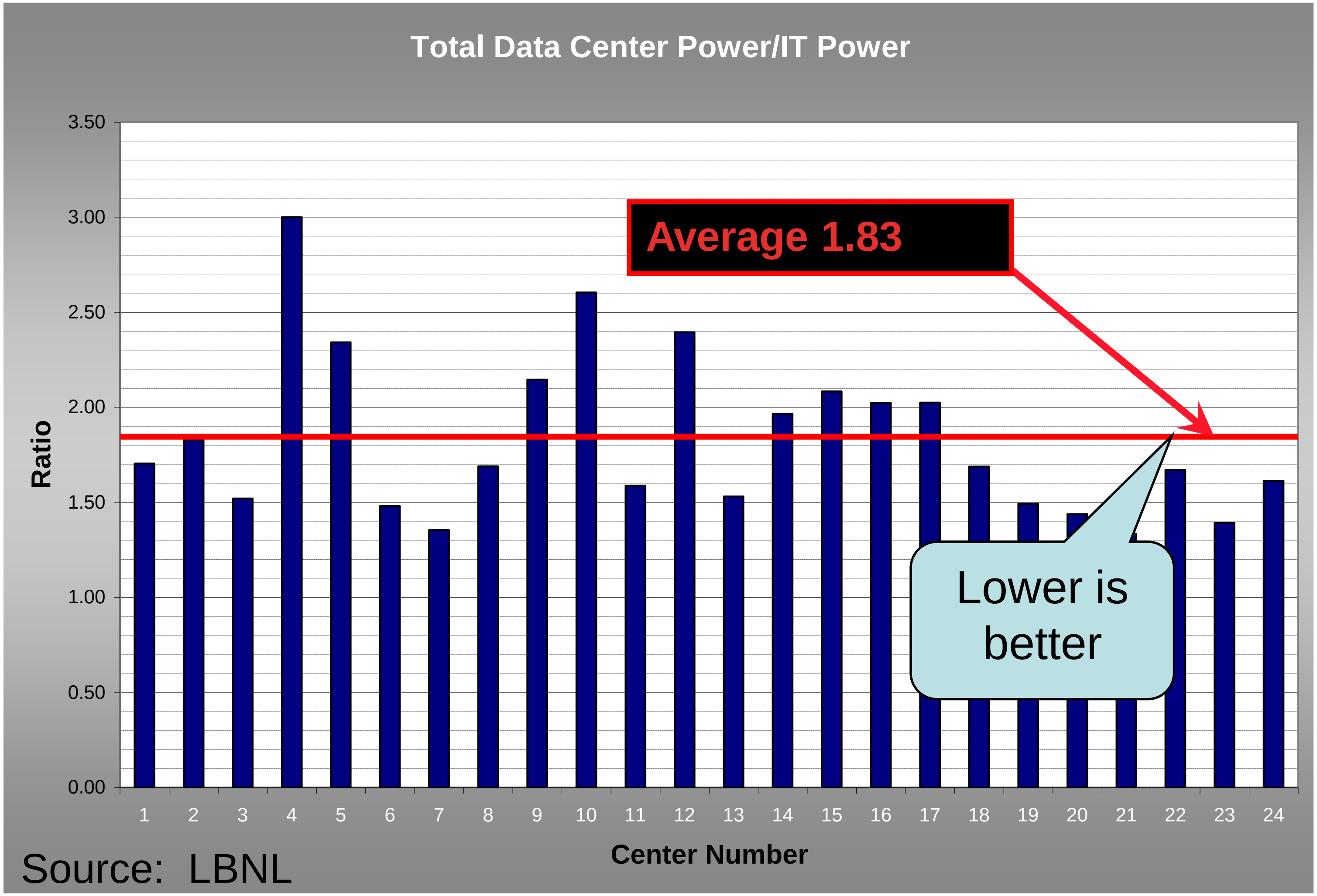
Better Practice
DCiE = 0.7

Best Practice
DCiE = 0.85

High level metric — IT/Total: DCiE

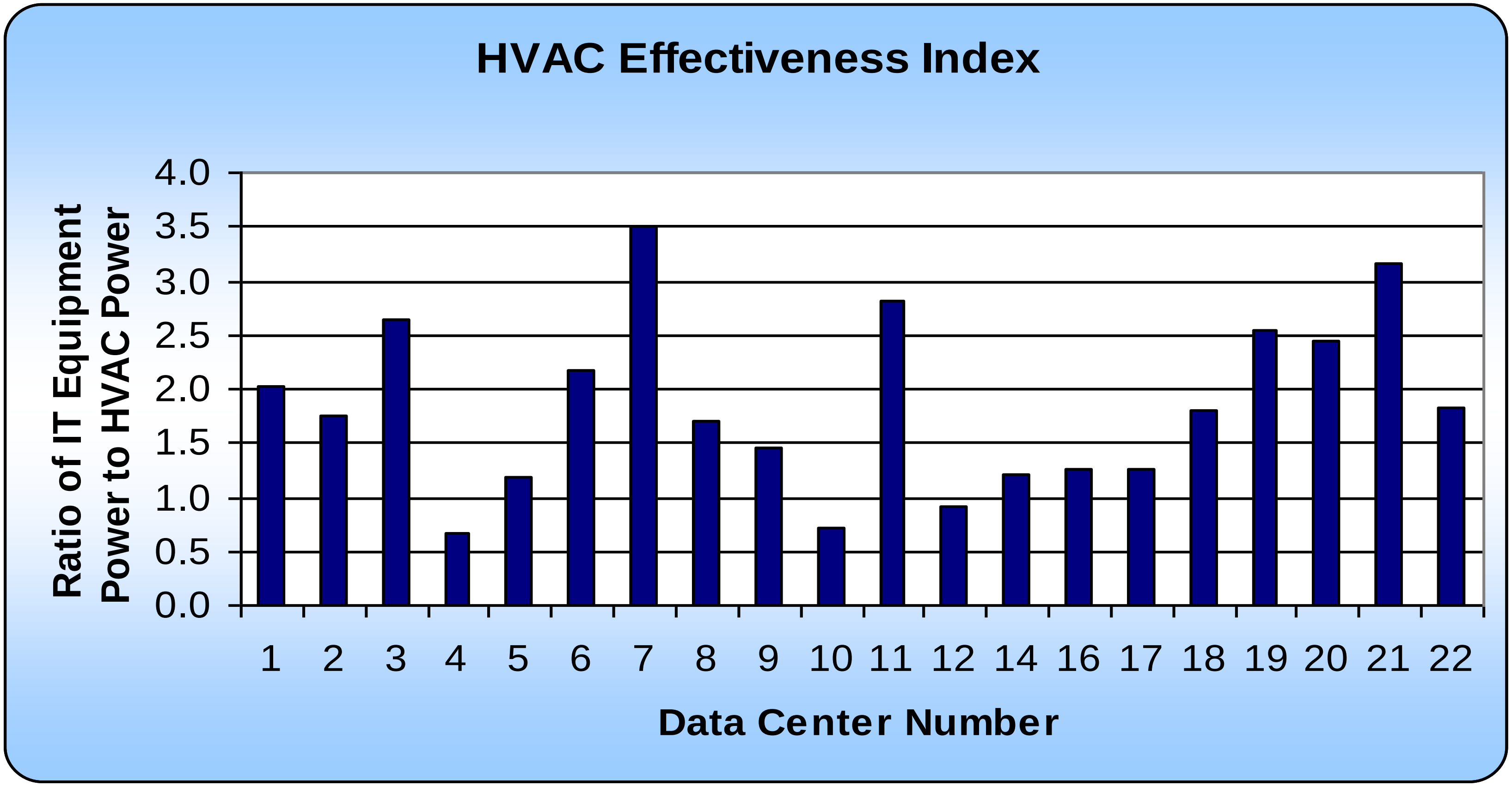


Inverse metric —Total/IT (PUE)



HVAC system effectiveness

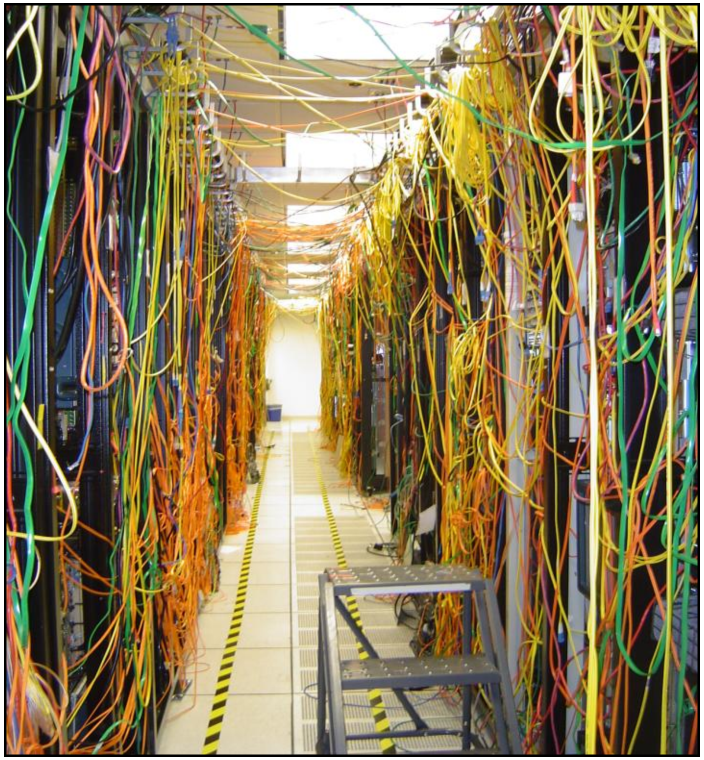
We observed a wide variation in HVAC performance



Benchmark results help identify best practices:

Examination of individual systems and components in the centers that performed well helped to identify best practices:

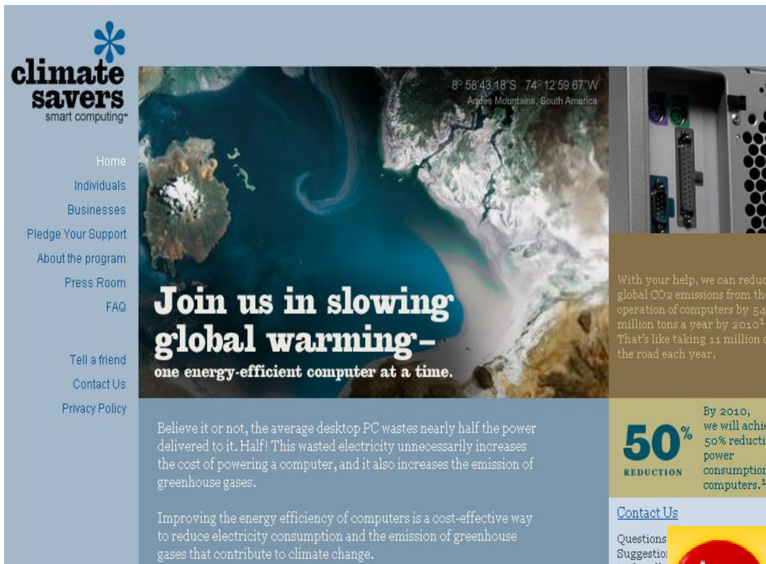
- Air management
- Right-sizing
- Central plant optimization
- Efficient air handling
- Free cooling
- Humidity control
- Liquid cooling
- Improving power chain
- UPSs and equipment power supplies
- On-site generation
- Design and M&O processes



The good news:

- Industry is taking action
  - IT manufacturers
  - Infrastructure equipment manufacturers
- Industry Associations are active:
  - ASHRAE
  - Green Grid
  - Uptime Institute
  - Afcom
  - Critical Facilities Roundtable
  - 7 X 24 Exchange
  - Silicon Valley Leadership Group
- Utilities and governments initiating programs to help

IT Industry taking action



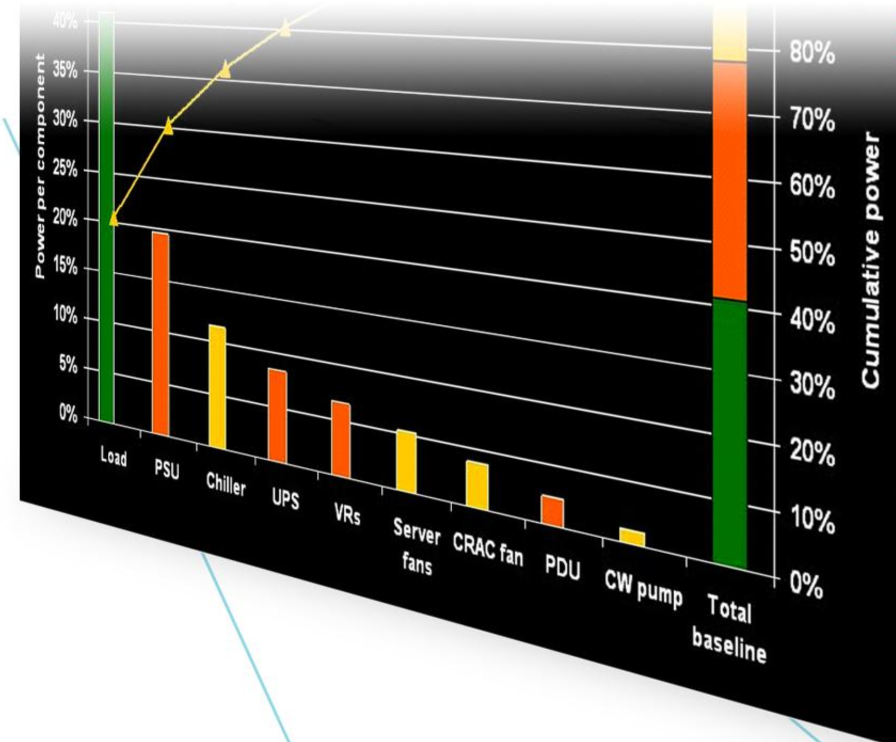
www.climatesaverscomputing.org

the green grid™

www.thegreengrid.com

Overview take aways

- Various meanings for “data centers”
- Benchmarking helps identify performance
- Benchmarking suggests best practices
- Efficiency varies
- Large opportunity for savings
- Industry is taking action and resources are available



Government Programs

Dale Sartor, PE

Industrial Technologies Program

- Tool suite & training
- Metrics & energy baselining
- Qualified specialists
- Case studies
- Certification of continual improvement
- Recognition of high energy savers
- Best practice information
- Best-in-Class guidelines
- R&D - technology development

Save ENERGY Now

Federal Energy Management Program

FEMP

- Best practices showcased at Federal data centers
- Pilot adoption of Best-in-Class guidelines at Federal data centers
- Adoption of to-be-developed industry standard for Best-in-Class at newly constructed Federal data centers

EPA

- Metrics
- Server performance rating & ENERGY STAR label
- Data center performance benchmarking

Industry

- Tools
- Metrics
- Training
- Best practice information
- Best-in-Class guidelines
- IT work productivity standard

Information Technology Industry Council

Uptime Institute

AFCOM

7X24 Exchange

Silicon Valley Leadership Group

Critical Facilities Roundtable

Public Law 109-431: EPA report

- **Purpose**: assess energy impacts on and from datacenters, identify energy efficiency opportunities, and recommend strategies to drive the market for efficiency
- **Goals**:
  - Inform Congress & other policy makers of important market trends, forecasts, opportunities
  - Identify and recommend potential short and long term efficiency opportunities and match them with the right policies

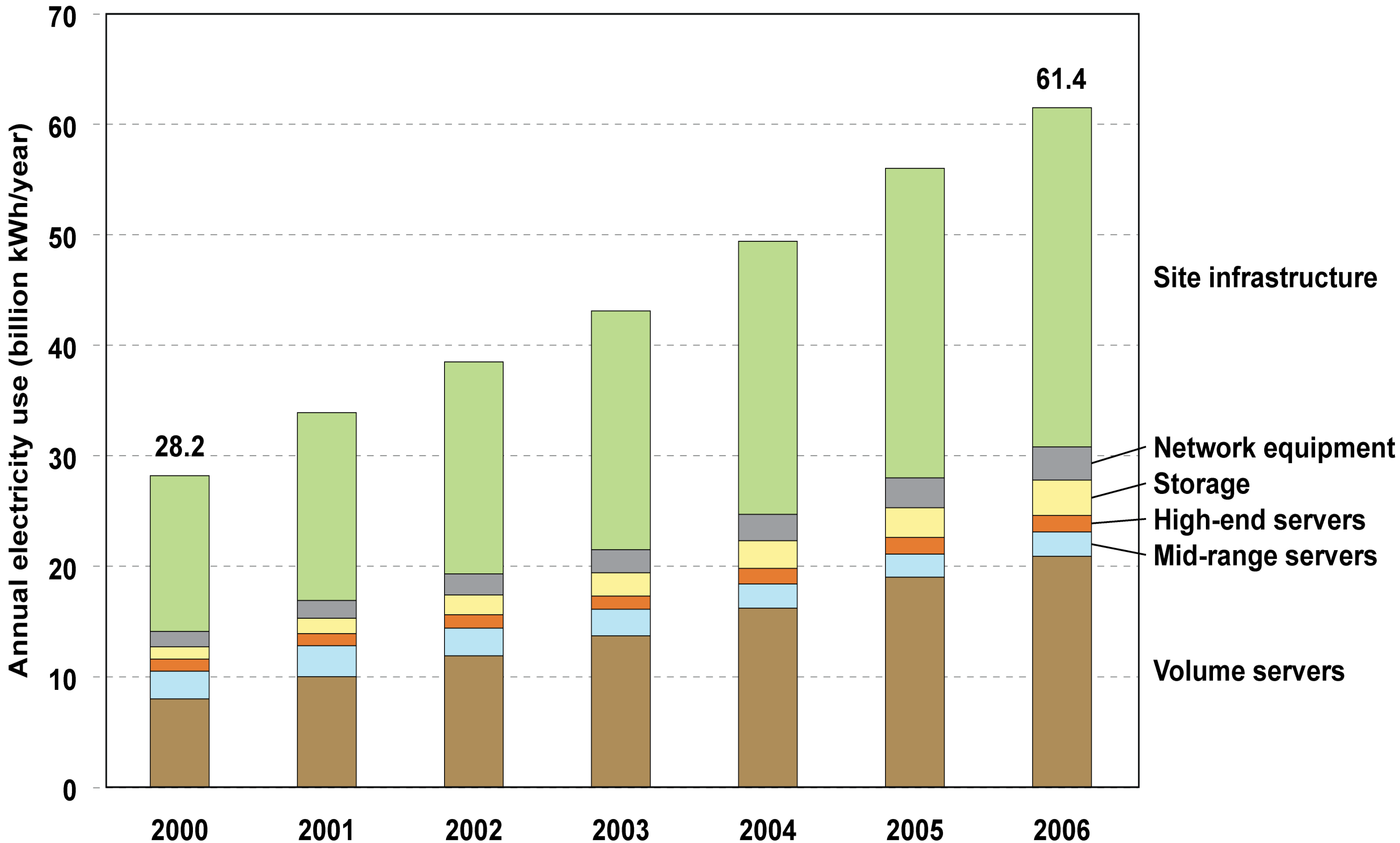
Report findings

Trends in Data Center Energy Use

- Sector consumed about 61 billion KWh in 2006
  - Equates to ~1.5% total U.S. electricity consumption and ~$4.5 billion
  - Federal sector: ~6 billion kWh and ~$450 million

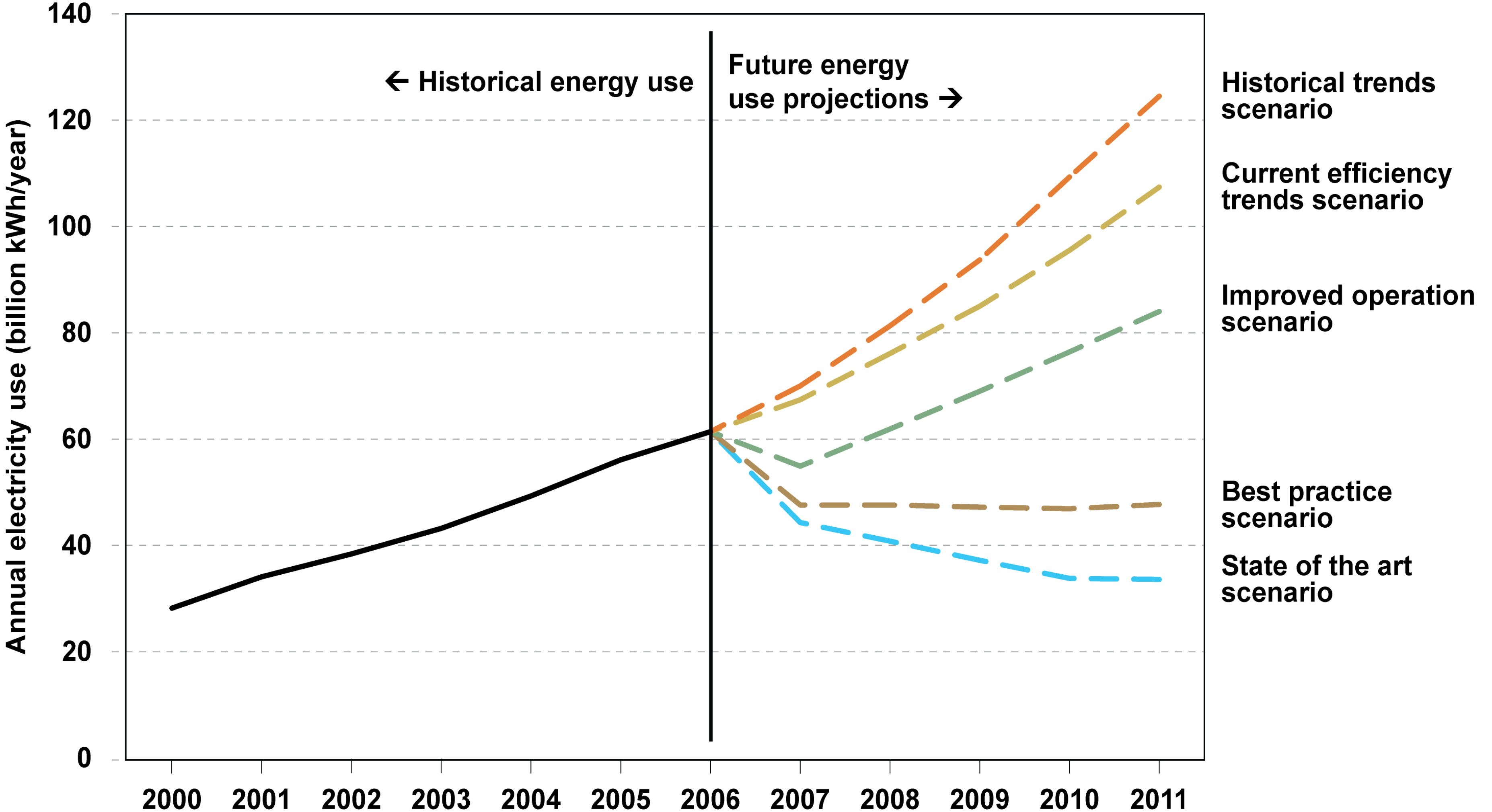
- Projected to increase to 100 billion kWh in 2011
  - Equates to ~2.5% of total U.S. electricity consumption and ~$7.4 billion

Electricity use by end-use - 2000 to 2006



Comparison of projected electricity use

All Scenarios 2007 - 2011



Report findings

Identified Key Barriers to Energy Efficiency

- Lack of efficiency definitions for equipment and data centers
  - Service output difficult to measure, varies among applications
  - Need for metrics and more data: *How do we account for computing performance?*
- Split incentives
  - Disconnect between IT and facilities managers
- Risk aversion
  - Fear of change and potential downtime – energy efficiency perceived as a change with uncertain value and risk

Report recommendations

- Standardized performance measurements for IT equipment and data centers
  - Development of benchmark/metric for data centers
  - ENERGY STAR label for servers, considering storage and network equipment
- Leadership by federal government
- Private Sector Challenge
  - CEOs conduct **DOE Save Energy Now** energy efficiency assessments, implement measures, and report performance
- Information on Best Practices
  - Raise awareness and reduce perceived risk of energy efficiency improvements in datacenter
  - Government partner with private industry: case studies, best practices
- Research and Development
  - Develop technologies and practices for datacenter energy efficiency (e.g., hardware, software, power conversion)

Federal Government activities

- Energy Star Products
- Energy Star Buildings
- Save Energy Now
- RD&D
- FEMP
- GSA

ENERGY STAR products

ENERGY STAR for servers

- Server energy demand drives data center power & cooling needs
- Goal: Create protocol to measure server energy efficiency
- Current Tier 1 Considerations
  - Power supply efficiency and/or net power consumption
  - Standard reporting requirements (standardized data sheet)
  - Power and temperature reporting requirements
  - Idle power
  - Power management and virtualization “hooks”
- Tier 2 Approach – utilize industry developed energy performance benchmarks to derive requirements
  - Will replace Tier 1 and will be a more holistic metric (system efficiency)

ENERGY STAR

ENERGY STAR Qualified Product Data Sheet
(SERVER MODEL NAME AND NUMBER)

- System Characteristics
  - Form factor (e.g., 1u, 2u, tower, blade chassis, etc.)
  - Available processor sockets
  - Processor information (model number, speed, # of cores, etc.)
  - Memory information (memory types, # Dimms, Dimm Size, etc.)
  - Power supply – number, redundancy, and size (Watts)
  - NIC information (#, speed)
  - Hard drive information (#, speed, size)
  - Installed operating systems (for purposes of testing)
  - OS listed as being supported
  - Other hardware features / accessories
- Air Flow Rate Information/Delta T
  - Total power dissipation for max load configuration
  - Delta T at exhaust of server for max load configuration (i.e., temperature rise across system at 100% load)
  - Size, position, and porosity of the inlet and exhaust grids/vents, including open, perforated, slotted, grille, mesh, etc.
  - Airflow at maximum fan speed (CFM)
  - Airflow at minimum fan speed (CFM)
- Available Power Management Features
- Virtualization Capability (e.g., embedded hypervisor, pre-installed software, etc.)
- Power and Temperature Measurement and Reporting
  - Compatible protocols for data collection
  - Ac / Input power available?
  - Dc power available (power supply output)
  - Input temperature available?
  - Output temperature available?
  - Processor utilization available?
- Power and Performance Data for base, typical and maximum configurations
  - Benchmark used and type of workload
  - Benchmark performance score
  - Maximum power[3]
  - Minimum power[3]
  - Idle power[3]
  - Power supply performance/net power consumption
  - Estimated kWh/year (*Assumptions TBD*)
- Link to manufacturer supplied savings calculator for customer specific configuration

Performance Data Sheet

- System Characteristics
- Air Flow Rate/Delta T
- Available Power Management Features
- Virtualization Capabilities
- Power and Temperature Measurement and Reporting
- Power and Performance Data (base, typical, max configuration)
- Link to Savings Calculator

Timeline

- Goal – Tier 1 specification finalized in early 2009
- Draft specifications released and stakeholder meetings in 2007 and 2008
- More Information
  - www.energystar.gov/productdevelopment (click on New Specs in Development)
  - Andrew Fanara, EPA, fanara.andrew@epa.gov

ENERGY STAR buildings

- U.S. Government energy management program to help building owners and managers reduce their energy consumption.
- Over 1,700 Partners operating more than 11 billion square feet of space (nearly 20% of space in the U.S.).
- More than 62,000 buildings measure and track their energy performance using ENERGY STAR’s Portfolio Manager on-line tool.
- ENERGY STAR labeled buildings use about 40 percent less energy than average buildings.
- More than 4,000 buildings have earned the ENERGY STAR label for energy efficiency.

Energy Star performance rating system

- Allows for peer group comparison
  - Compares a building's energy performance to its national peer group.
  - Allows owners with multiple facilities to compare performance across a portfolio of buildings.
- Based on actual as-billed energy data.
- Serves as a whole building indicator
  - Captures the interactions of building systems not individual equipment efficiency.

Goals for the ENERGY STAR Data Center rating

- Build on existing ENERGY STAR methods and platforms. Methodology similar to existing ENERGY STAR ratings (1-100 scale).
- Usable for both stand-alone data centers, as well as data centers housed within office or other buildings.
- Assess performance at the building level to explain how a building performs, not why it performs a certain way.
- Offer the ENERGY STAR label to data centers with a rating of 75 or higher (performance in the top quartile).

Rating based on Data Center Infrastructure Efficiency (DCiE)

- IT Energy/Total Energy
- Measure of infrastructure efficiency
  - Captures impact of cooling and support systems
  - Does not capture IT efficiency
- Best available whole building measure at this time
  - Ideal metric would be measure of useful work/energy use.
  - Industry still discussing how to define useful work.
- Express DCiE ranking as ENERGY STAR 1 to 100 rating
  - Each point on rating scale equals 1 percentile of performance.
  - Adjust for operating constraints outside of the owner/operators control (e.g. climate).
  - Factors for adjustment to be determined based on results of data collection and analysis.

Development plan

- Gather monthly data from at least 100 data centers for a 12-month period (over 200 have signed up)
- A variety of information is being provided:
  - Climate zone (zip code)
  - Type of data center (function)
  - Reliability (Tier Level)
  - Total IT plug energy (12 months of data)
  - Total facility energy usage (12 months of data for all fuels)
- Data collected from a wide variety of facilities (large/small, stand-alone/within larger bldg, etc.)
- Analyze data to develop rating models.
- Launch ENERGY STAR Data Center Infrastructure Rating in Portfolio Manager.

DOE Industrial Technologies Program

Working to improve the energy efficiency of U.S. industry

U.S. industry consumes 32 quadrillion Btu per year -- almost 1/3 of all energy used in the nation

Partnerships with energy-intensive industries are key to ITP's success:

- 5 quads of energy savings, 86 MMTCE reduction

Data centers are information factories

Save Energy Now is working to reduce industrial energy intensity 25% by 2017

Data centers are an important and growing industry:

- Consumed 1.5% of all electricity in the U.S. in 2006
- Power demand is growing about 12% per year
- Power and cooling systems are "industrial" in scale and complexity

Save Energy Now: products & services

Tools
- Process Heating
- Steam Systems
- Plant Energy Profiler
- Motors & Pumps
- Fans

Information
- Website
- Information Center
- Tip Sheets
- Case studies
- Webcasts

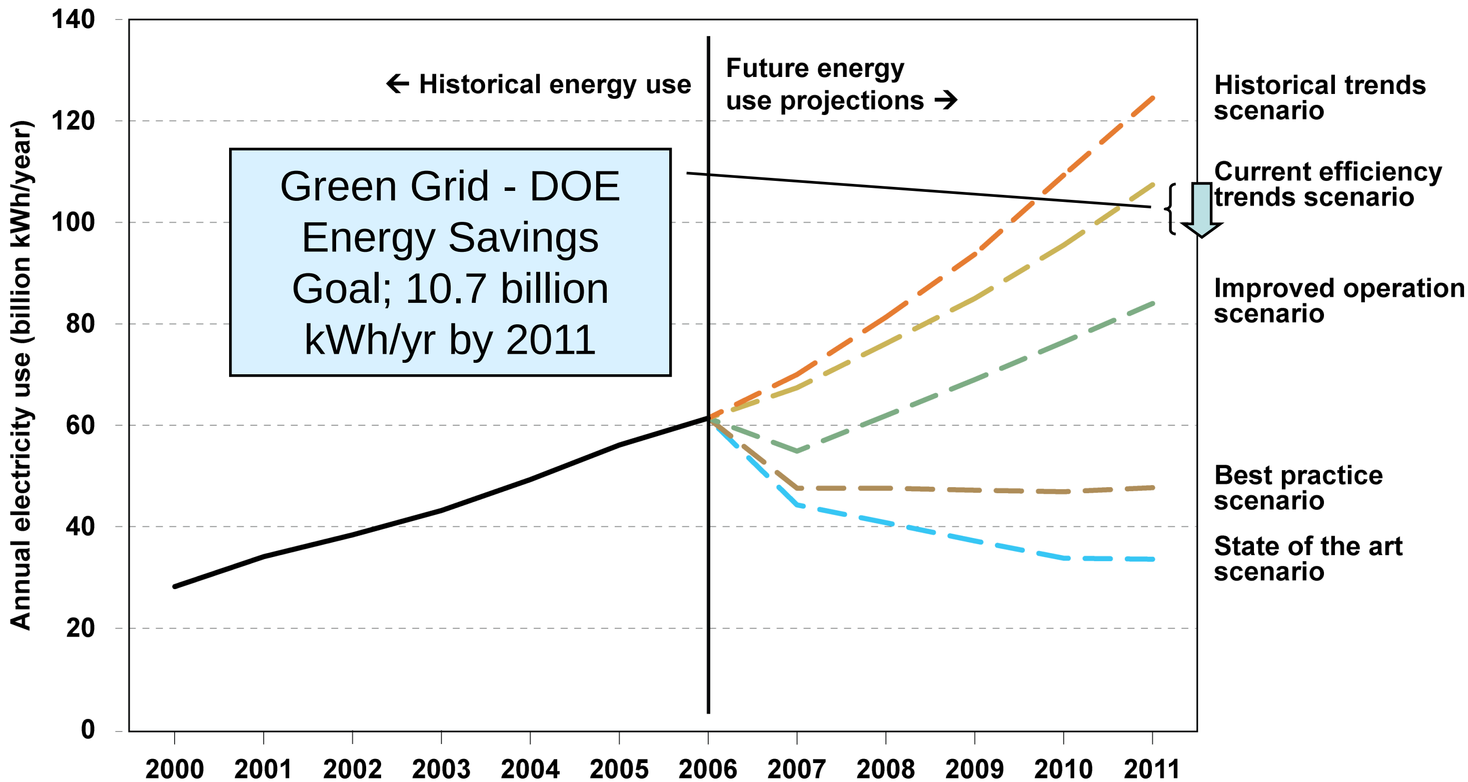
Training
- Basic
- Advanced
- Qualified Specialist

Assessments
- Energy Savings Assessments
- Industrial Assessment Centers

DOE-Green Grid partnership goals

2011 goal is 10% energy savings overall in U.S. data center

- 10.7 billion kWh
- Equivalent to electricity consumed by 1 million typical U.S. households
- Reduces greenhouse gas emissions by 6.5 million metrics tons of CO_2 per year



Collective goals

By 2011:

- 3,000 data centers completed awareness training through classes or webcasts via partners
- 1,500 mid-tier and enterprise-class data centers will have applied Assessment Protocols and Tools to improve data center energy efficiency by 25% (on average)
  - 200 enterprise-class data centers will have improved their energy efficiency by 50% (on average) via aggressive measures
- 200 Qualified Specialists certified to assist data centers

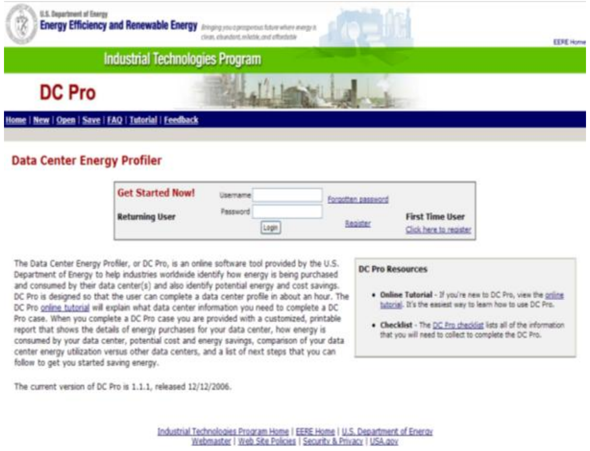
DOE Save Energy Now Data Center program elements

1. Establish metrics for data center energy intensity
   - IT and infrastructure
   - Energy cost ($), source energy (Btu), and carbon emissions (M tons)
   - Specified Best-in-Class targets for various types of data centers
2. Create technologies, tools and guidelines to drive continuous improvement
   - Develop and test “DC Pro” Tools
   - Create and publicize Save Energy Now case studies
3. Create best practice information and a training curriculum
4. Develop Qualified Specialists program for Data Centers
5. Support third-party certification process to validate energy intensity improvement and Best-in-Class
6. Provide recognition for data centers that achieve a certain level of energy savings
7. Create guidelines for “Best-in-Class” data centers and validate with Technology Demonstrations
8. Create and implement a collaborative research program with industry

“DC Pro” Tool Suite

Tools to profile baseline energy use of data center and identify key energy-saving opportunities

- Determine general performance of the data center
- Benchmark subsystems
- Assess energy savings potential
- Track energy intensity improvement
- Provide quantification of key metrics including cost ($), primary energy (Btu), and carbon



U.S. Department of Energy
Energy Efficiency and Renewable Energy
EERE Home
Industrial Technologies Program
DC Pro
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Data Center Energy Profiler

Get Started Now!
Returning User
Username
Password
Login
Forgotten password
Register
First Time User
Click here to register

The Data Center Energy Profiler, or DC Pro, is an online software tool provided by the U.S. Department of Energy to help industries worldwide identify how energy is being purchased and consumed by their data center(s) and also identify potential energy and cost savings. DC Pro is designed so that the user can complete a data center profile in about an hour. The DC Pro online tutorial will explain what data center information you need to complete a DC Pro case. When you complete a DC Pro case you are provided with a customized, printable report that shows the details of energy purchases for your data center, how energy is consumed by your data center, potential cost and energy savings, comparison of your data center energy utilization versus other data centers, and a list of next steps that you can follow to get you started saving energy.

DC Pro Resources

- **Online Tutorial** - If you're new to DC Pro, view the online tutorial. It's the easiest way to learn how to use DC Pro.
- **Checklist** - The DC Pro checklist lists all of the information that you will need to collect to complete the DC Pro.

The current version of DC Pro is 1.1.1, released 12/12/2006.

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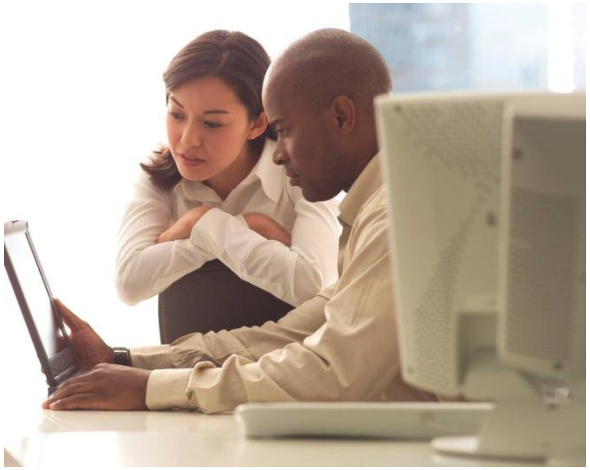

Key milestones

• DC Profiling tool version 1.0	October ‘08
• Training curriculum piloted	May – Nov. ‘08
• DC Pro Electric System Tool beta release	September ’08
• Innovative Technology workshop	October ‘08
• Qualified Specialist training	June ‘09

By 2011

Save ENERGY Now

Products

- DC Pro tool
- Assessment protocols
- Training
- Case studies
- Best practices
- Best-in-Class guidelines
- Technology demonstrations

Market Delivery

- 200 Qualified Specialists
- Suppliers
- Engineering firms
- Utilities
- Associations and technical societies

Data Center Results

- 10 billion kWh per year saved
- 3,000 people trained on tools and assessment protocols
- 1,500 data centers improve energy efficiency > 25%
- 200 data centers improve energy efficiency >50%

DOE Data Center program

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202-586-7234

Information Tech. R&D program

Gideon Varga

www.eere.energy.gov/industry

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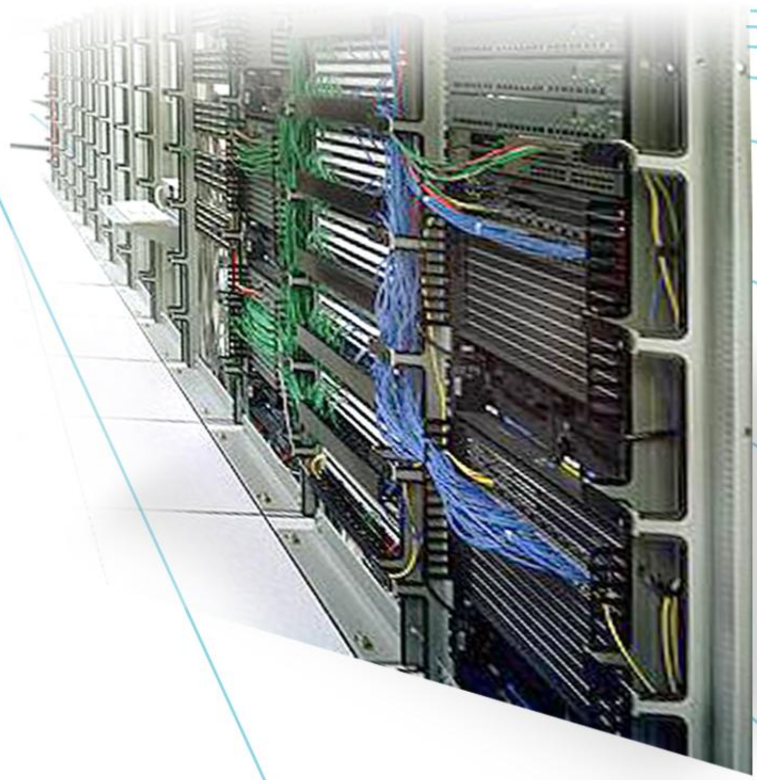
202-586-0082

Federal Energy Management Program

- Workshops and training
  - GovEnergy 2008 (Phoenix, August 7)
  - Labs21/DataCenter21 (San Jose, September 15)
  - Webinars and forums for peer to peer exchange
- Technical assistance
  - Use of Profiling and Assessment tools
  - Showcase projects
- Procurement specifications (starting with servers and UPS)
- Best practice case studies
- DOE data center facility survey
- Strategic alliances with other Federal agencies (e.g. GSA) to coordinate Federal datacenter activities including establishing performance targets
- Federal Energy Management Program awards
- Facilitating energy savings in data centers through energy savings performance contracts

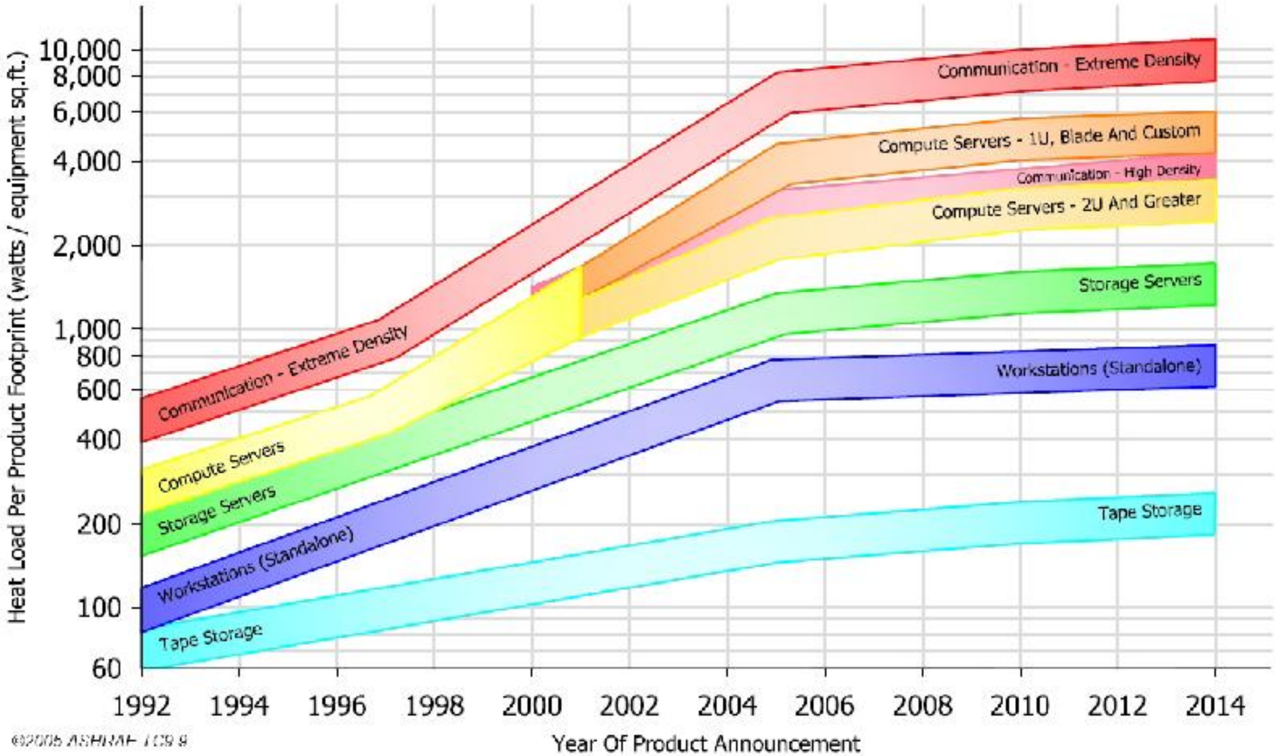


IT Equipment Efficiency

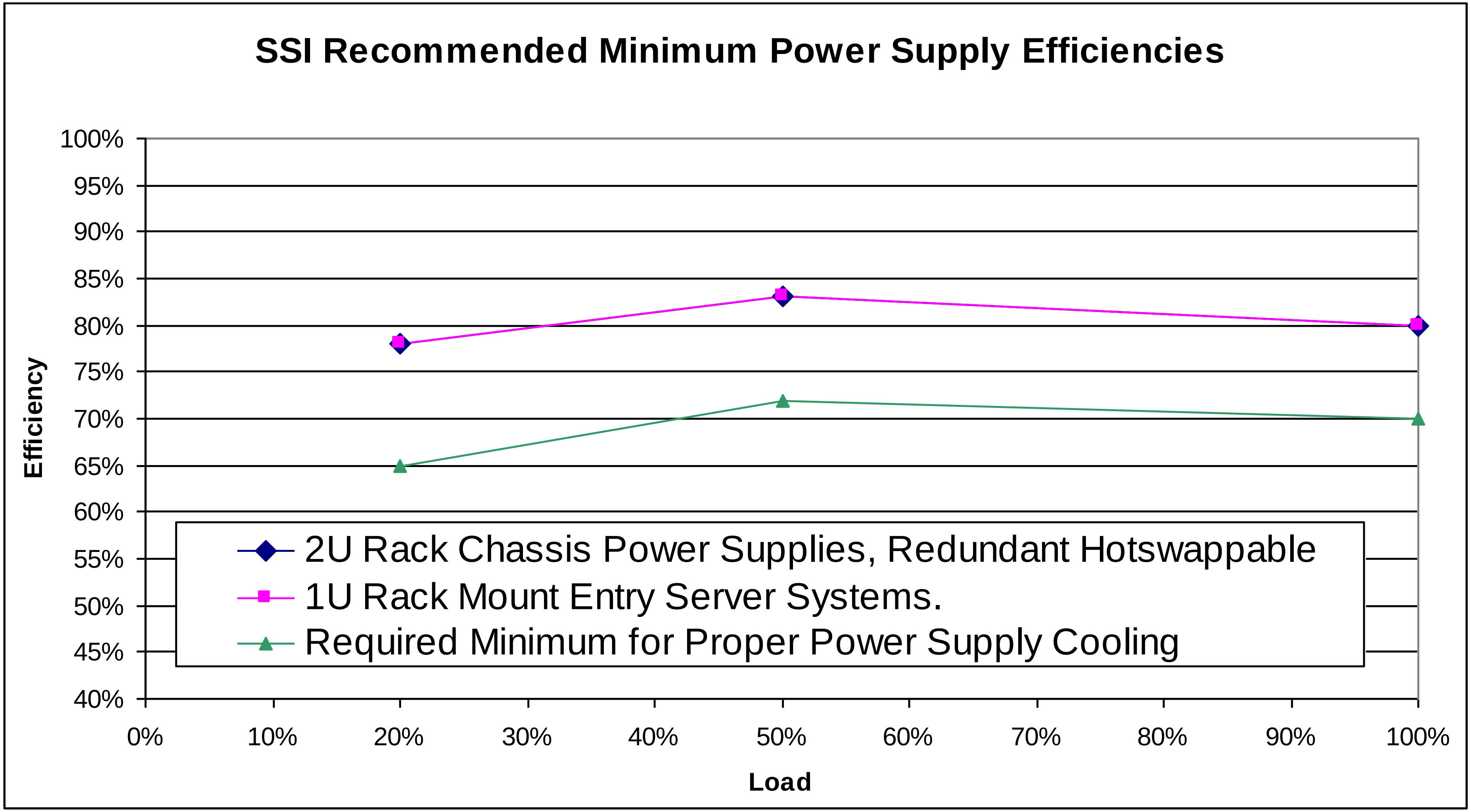
IT equipment load

- Predicting IT loads
  - Over sizing, at least initially, is common
  - Implement modular and scalable approaches
- IT loads can be controlled
  - Power supply options
  - Server efficiency
  - Software efficiency (Virtualization, MAID, etc.)
  - Redundancy and back-up power
  - Low power modes
- Reducing IT load has a multiplier effect

ASHRAE prediction of intensity trend



Efficient power supplies



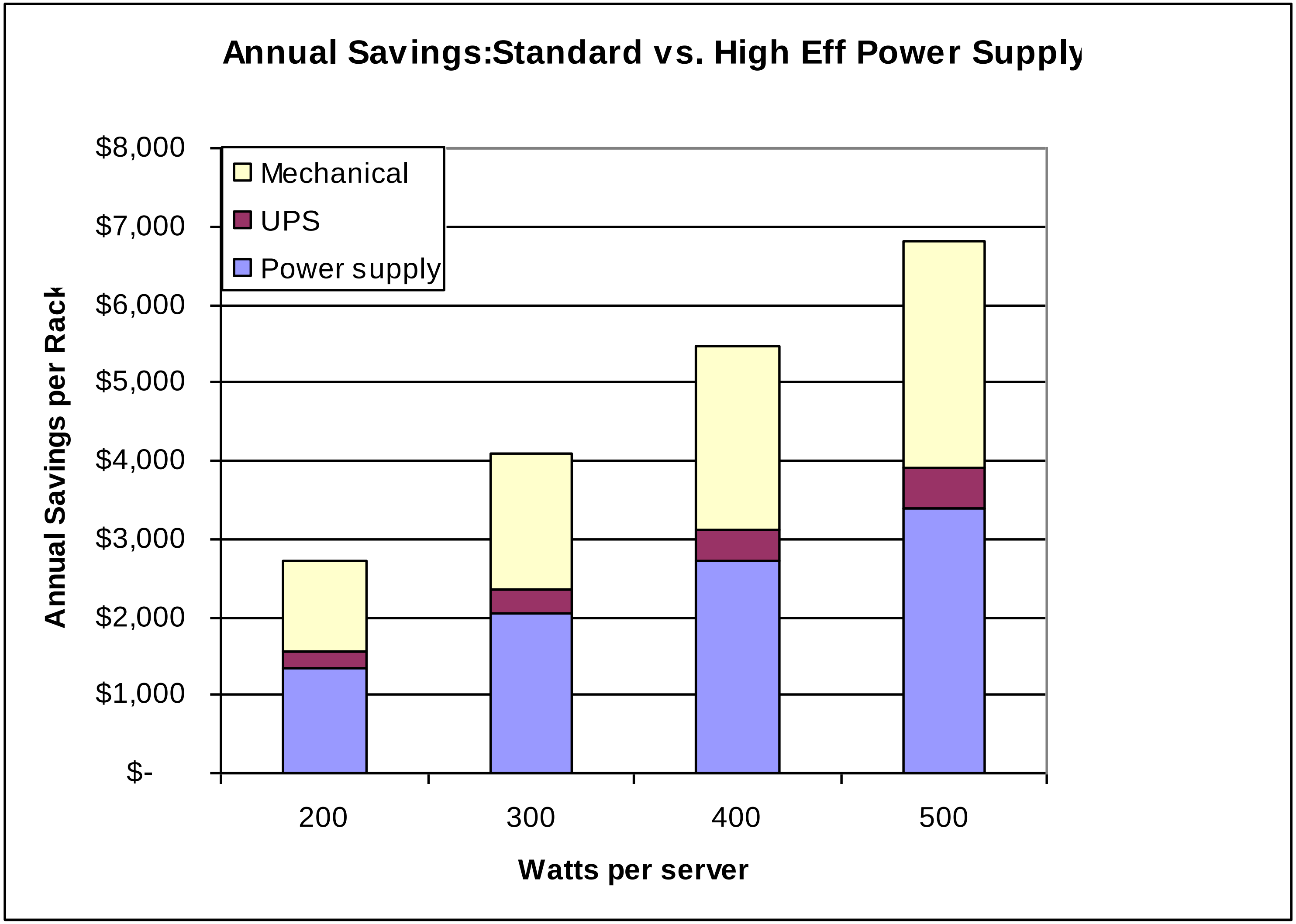
Server System Infrastructure (SSI) Initiative (SSI members include Dell, Intel, and IBM)

Power supply, per server savings

Power Supplied Per Server (Watts)	Annual Savings Using a SSI Recommended Minimum Efficiency Supply[1]	Annual Savings Including Typical Cooling Energy[2]
200	$ 37	$ 65
300	$ 56	$ 97
400	$ 74	$ 130
500	$ 93	$ 162

- 1. Assuming $0.10/kWh, 8760 hr/yr, 85% efficient UPS supply, 72% efficiency baseline PS
- 2. Cooling electrical demand is estimated 75% of rack demand, the average ratio of 12 benchmarked datacenter facilities

Power supply savings add up



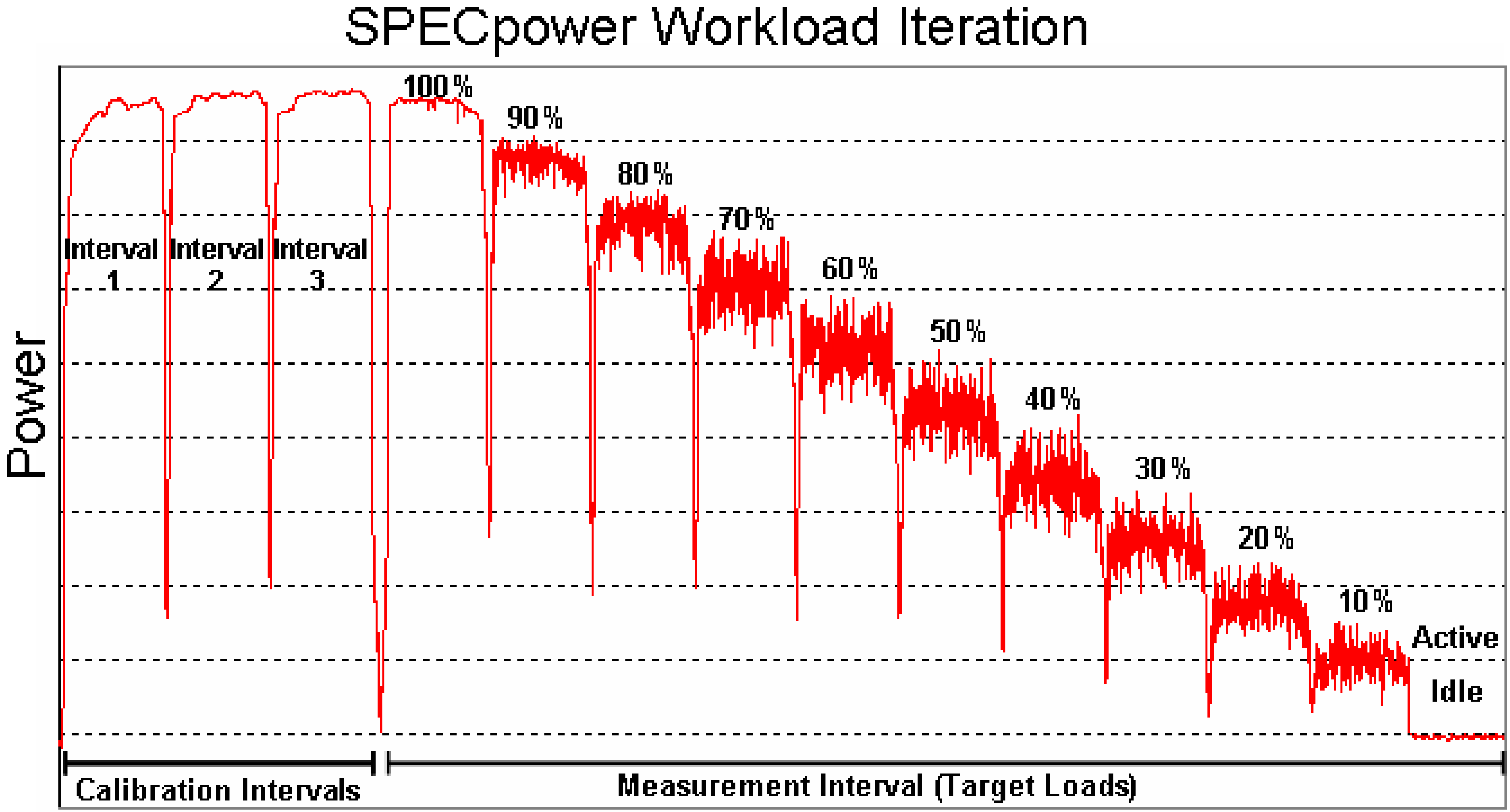
High efficiency servers

Energy savings and potential utility incentive for installation of **three** new High Efficiency Servers.

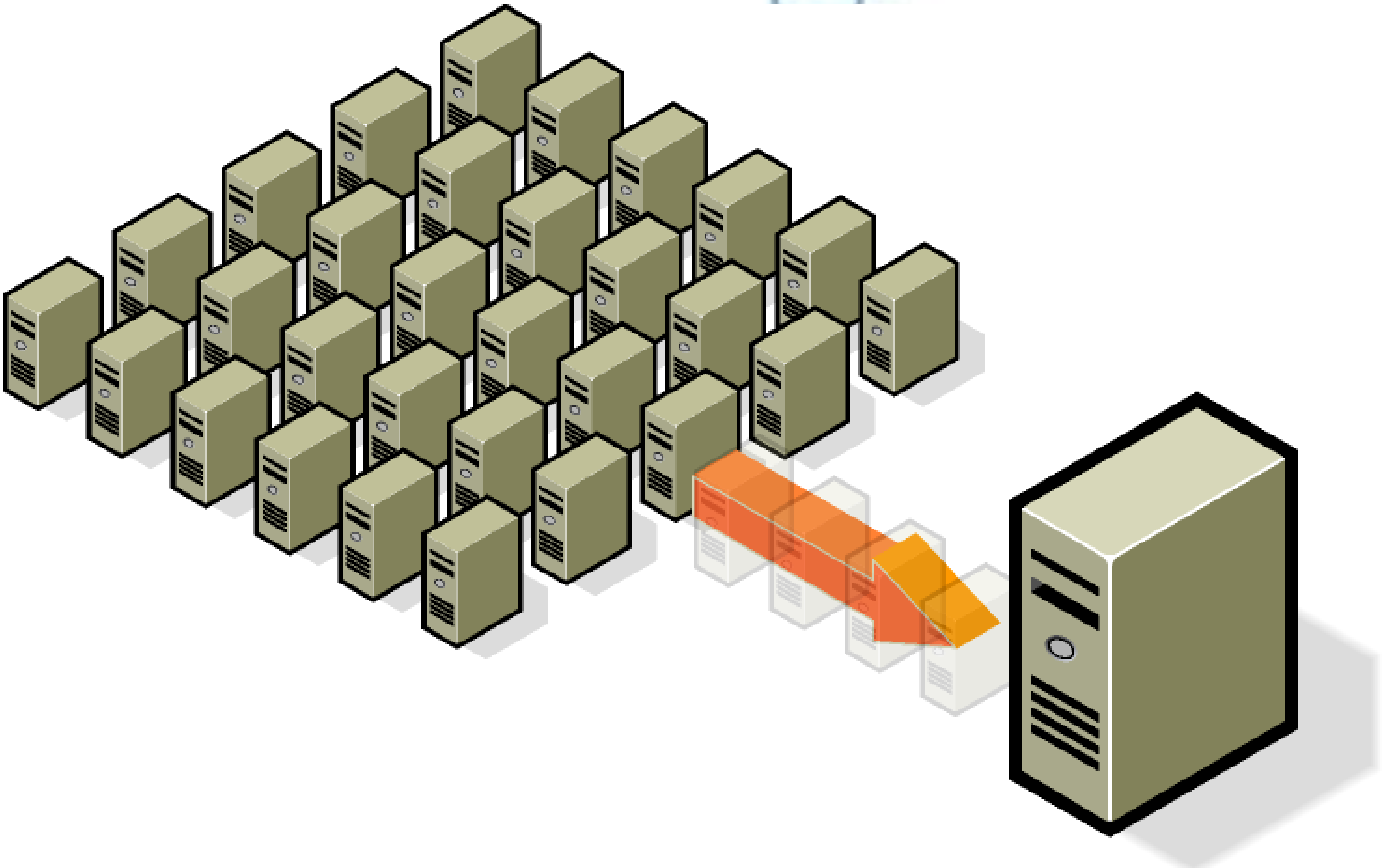
	Baseline Usage	Installed Usage	Energy Savings	Electric Cost Savings	PG&E Incentive	Incremental Installation Cost
	kWh/yr	kWh/yr	kWh/yr	$/yr	$	$
Install High Efficiency Servers - Direct Energy Savings	24,538	4,941	19,598	$ 2,352	$ 1,960	n/a
Install High Efficiency Servers - Indirect HVAC Savings	9,003	1,813	7,190	$ 863	$ 1,007	n/a
Combined	33,541	6,753	26,788	$ 3,215	$ 2,967	n/a

Slide courtesy Rumsey Engineers

Coming soon - power performance metrics e.g. Standard Performance Evaluation Corp (SPEC)



Server virtualization



Server virtualization

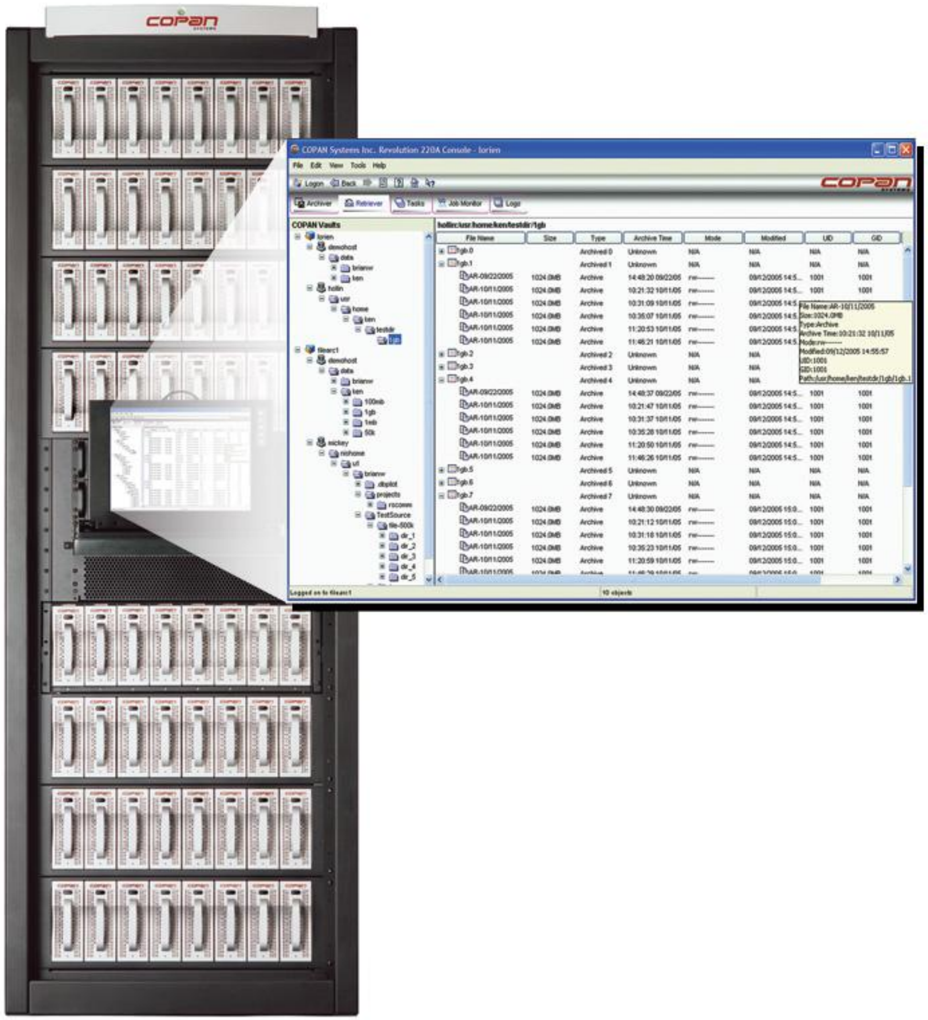
- Energy savings and potential utility incentive for Server Virtualization.
- Number of servers before virtualization: 50.
- Number of servers after virtualization: 30.

	Baseline Usage	Installed Usage	Energy Savings	Electric Cost Savings	PG&E Incentive	Total Installation Cost
	kWh/yr	kWh/yr	kWh/yr	$/yr	$	$
Install Virtual Server - Direct Energy Savings	98,550	59,130	39,420	$ 4,730	$ 3,154	$ 70,000
Install Virtual Server - Indirect Equipment Support Savings	60,636	36,382	24,254	$ 2,911	$ -	$ -
Combined	159,186	95,512	63,674	$ 7,641	$ 3,154	$ 70,000

Massive array of idle disks (MAID)

- MAID is designed for Write Once, Read Occasionally (WORO) applications.

- In a MAID each drive is only spun up on demand as needed to access the data stored on that drive.



Massive array of idle disks (MAID)

- Energy savings and possibly utility incentive for installation of a MAID system.
- Install one fully-loaded MAID cabinet with a total storage capacity of 448TB in lieu of a traditional cabinet of the same capacity.

	Baseline Usage	Installed Usage	Energy Savings	Electric Cost Savings	PG&E Incentive	Incremental Installation Cost
	kWh/yr	kWh/yr	kWh/yr	$/yr	$	$
Install Maid System - Direct Energy Savings	278,450	75,118	203,332	$ 26,551	$ 16,267	$ 224,000
Install Maid System - Indirect HVAC Savings	102,163	27,561	74,602	$ 9,742	$ 10,444	$ -
Combined	380,613	102,679	277,934	$ 36,293	$ 26,711	$ 224,000

The value of one watt saved at the server CPU

1 Watt at CPU

= 1.25 Watts at entry to server (80% efficient power supply)

= 2.5 Watts including power distribution (UPS) and cooling (2.0 PUE)

= 22 kWh per year

= $2.20 per year (assuming $0.10/kWh)

= $7.50 of infrastructure cost (assuming $6/W)

- **Total Cost of Ownership (TCO) Perspective = $14 (assuming three year life of server)**
- **Typical added cost of 80 plus power supply $3 - $5.**
  - **Typical value - $168 (assumes 15 Watts saved at power supply not CPU)**

Slide courtesy Rumsey Engineers

IT take aways

- Efficient power supplies have large annual savings
- Efficient power supplies reduce infrastructure power consumption
- Efficient servers are orders of magnitude more efficient than older equipment
- Public utility incentives may be available
- Virtualization can eliminate many servers
- Software to limit spinning discs has large promise
- Saving one watt at the server saves 2.5 watts overall

Break